SPECTRAL CHARACTERIZATION OF ANALOG SAMPLES IN ANTICIPATION OF OSIRIS-REx'S ARRIVAL AT BENNU. K. L. Donaldson Hanna[1], D. L. Schrader[2], N. E. Bowles[1], B. E. Clark[3], E. A. Cloutis[4], H. C. Connolly Jr.[5], V. E. Hamilton[6], L. P. Keller[7], D. S. Lauretta[8], L. F. Lim[9] and T. J. McCoy[10], [1]University of Oxford (Kerri.DonaldsonHanna@physics.ox.ac.uk), [2]Arizona State University, [3]Ithaca College, [4]University of Winnipeg, [5]Rowan University, [6]Southwest Research Institute, [7]Johnson Space Center, [8]University of Arizona, [9]Goddard Spaceflight Center, [10]Smithsonian Institution.

Introduction: NASA's Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) mission successfully launched on September 8th, 2016. During its rendezvous with near-Earth asteroid (101955) Bennu beginning in 2018, OSIRIS-REx will characterize the asteroid's physical, mineralogical, and chemical properties in an effort to globally map the properties of Bennu, a primitive carbonaceous asteroid, and choose a sampling location [e.g. 1]. In preparation for these observations, we spectrally characterized a suite of analog samples across visible, near- and thermal-infrared wavelengths and used these in initial tests of phase detection and abundance determination software algorithms. Here we present the thermal infrared laboratory measurements of the analog sample suite measured under asteroid-like conditions, which are relevant to the interpretation of spectroscopic observations by the OSIRIS-REx Thermal Emission Spectrometer (OTES) [2, 3]. This suite of laboratory measurements of asteroid analogs under asteroid-like conditions is the first of their kind.

Analog Samples: Analog samples in this study included physical mixtures of minerals and a suite of chondritic meteorites. Well-characterized terrestrial minerals were provided by the Smithsonian Mineral and Meteorites Collection (SMCC) and well-characterized meteorites were provided by the SMCC, the Antarctic Meteorite Collection of the United States, and Arizona State University (ASU). Further discussion of the analog suite can be found in Schrader et al. [4].

Experimental Methods: Thermal infrared (TIR) emissivity measurements were made under Earth-like (ambient) and simulated asteroid environment (SAE) conditions using the Simulated Lunar Environment Chamber (SLEC) within the Planetary Spectroscopy Facility at the University of Oxford. The experimental setup and calibration of SLEC have been previously described by Thomas et al. [5, 6]. Under ambient conditions, samples are heated from below to 80°C while the environment chamber is held at ambient pressure (~1000 mbar N_2) and temperature (~28°C). Bennu's near surface environment, in particular the thermal gradient experienced in the upper hundreds of microns in the regolith, is simulated by: (1) removing atmospheric gases from inside the chamber (< 10^{-4} mbar), (2) cooling the interior of the chamber to < -150°C, and (3) heating the samples from below and above until the maximum brightness temperature of the sample is ~75°C. TIR spectra were collected using a Bruker IFS66v Fourier Transform Infrared (FTIR) spectrometer at a resolution of 4 cm^{-1} from ~2400 – 400 cm^{-1} (~4 – 25 μm).

Previous laboratory measurements of fine particulate (< 100 μm) silicate minerals and lunar soils have demonstrated the importance of making TIR spectral

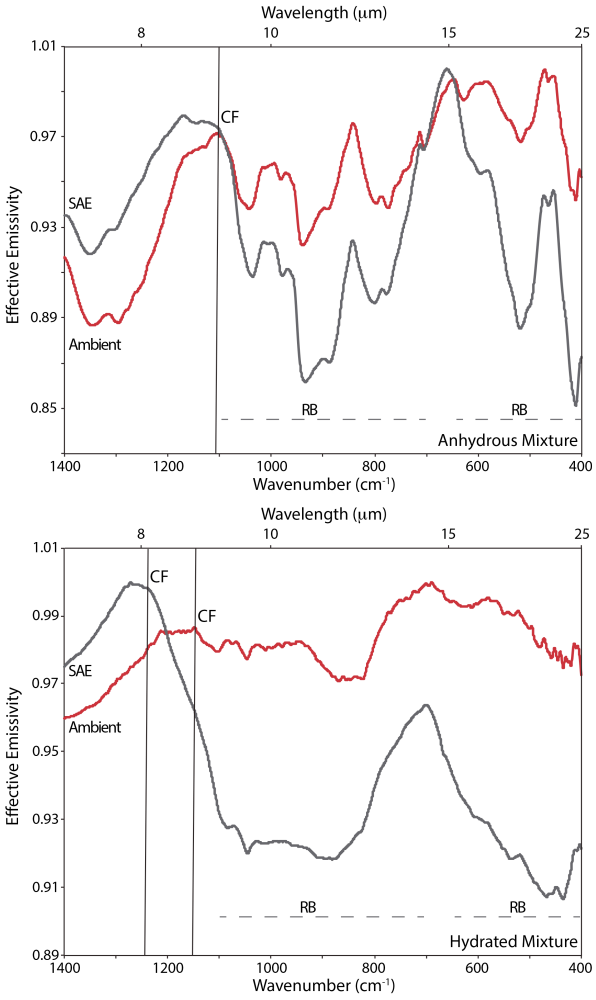

Figure 1. (Top) Spectra of a physical mixture dominated by anhydrous silicate minerals (olivine is the most abundant mineral). **(Bottom)** Spectra of a physical mixture dominated by hydrated silicates (saponite and lizardite are the most abundant minerals).

measurements under the appropriate near-surface conditions (simulated thermal gradient) as the Christiansen Feature (CF), an emissivity maximum diagnostic of composition, is known to shift to higher wavenumbers and the spectral contrast between the CF and the fundamental vibration bands (also diagnostic of composition and known as the reststrahlen bands or RB) is known to increase [e.g. 6-8]. These results have demonstrated the sensitivity of TIR spectra to the near-surface environment under which they are measured.

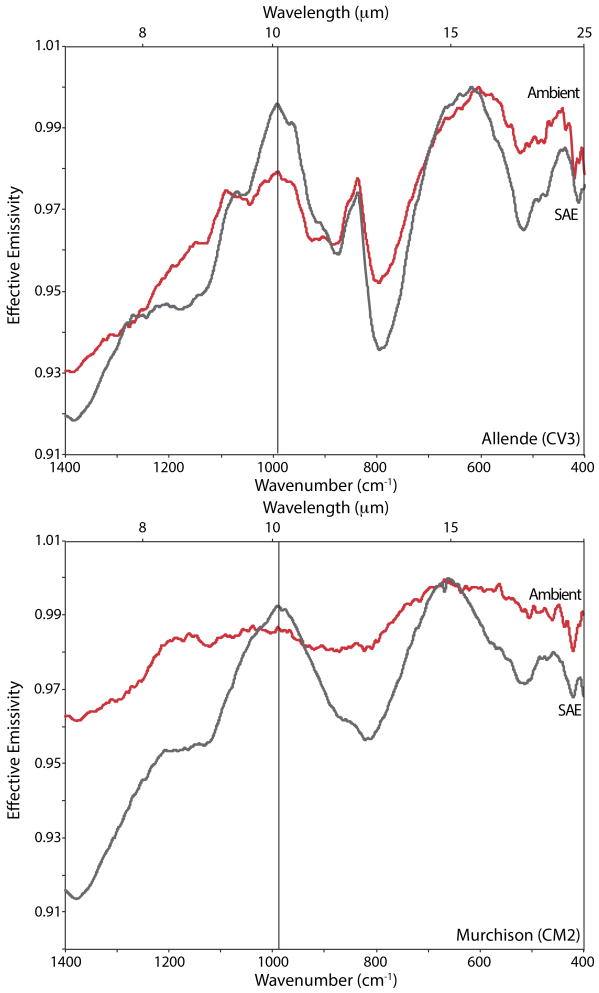

Figure 2. (Top) Spectra of carbonaceous chondrites Allende (CV3) and **(Bottom)** Murchison (CM2).

Results: Emissivity spectra in Figure 1 show the utility of TIR spectral features for distinguishing between samples dominated by anhydrous versus hydrated silicates as the anhydrous sample, whose most abundant mineral is olivine, has distinct RB between ~1100 – 700 cm^{-1} and 600 – 400 cm^{-1}. As seen in Figure 1, SAE spectra of physical mixtures dominated by the hydrated silicates saponite and lizardite show a larger shift in the CF and a greater increase in the spectral contrast between the CF and RB than SAE spectra of anhydrous samples.

Emissivity spectra of carbonaceous chondrites Allende (CV3) and Murchison (CM2) measured under ambient and SAE conditions are shown in Figure 2. Similar to the SAE spectra of the physical mixtures, SAE spectra of carbonaceous chondrites dominated by hydrated silicates like Murchison show a greater increase in spectral contrast than carbonaceous chondrites dominated by anhydrous silicates like Allende. Comparisons of SAE and ambient spectra for the other carbonaceous chondrites show that the degree to which the spectral contrast increases correlates with meteorite group. SAE spectra of CM and CV meteorites show an increase in contrast of the spectral feature near 1000 cm^{-1} (~5 %) whereas SAE spectra of CI, CK, CO, and CR show little to no increase (< 2 %) [6].

These initial laboratory measurements of physical mixtures and carbonaceous chondrites suggest that using spectra measured under simulated asteroid conditions to interpret Bennu's surface composition could be very important to reducing uncertainties in the estimated modal phase abundances. Taking these effects into account is particularly important for regoliths dominated by fine particulate materials.

Future Work: To better constrain Bennu's surface composition through the interpretation of remote sensing observations, we must better characterize the effects of particle size, crystallinity, and composition. In particular the effects of organic material and amorphous silicates on TIR spectra need to be studied. Future studies are planned to constrain the particle size fractions needed in the abundance determination algorithms to best interpret TIR spectra. In addition, lab measurements are needed of samples with increasing amounts of organic material and amorphous silicates.

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